1 **Climate Change and Ozone Depletion**

2 **The Atmosphere**

- Earth's atmosphere contains roughly:

3 **Atmospheric Layers**

- The stratosphere contains 99.9% of the ozone.
- Ozone depletion occurs in the stratosphere.

- The troposphere contains the weather, the majority of oxygen, and living organisms.
- Global warming and climate change occurs in the troposphere.

4 **Stratospheric Ozone**

- A thin veil of renewable ozone exists in a band of the upper stratosphere,17-26 km above the Earth's surface and is formed by UV rays reacting with oxygen.
- Stratospheric ozone absorbs about 99% of the harmful incoming ultra violet (UV) radiation (A, B and C) from the sun and prevents it from reaching the Earth's surface.

5 **Effects of UV Radiation**

- As well as all the well known health problems associated with ultraviolet radiation, e.g. sunburn, cancers and cataracts, UV-B radiation is likely to cause:
  - decrease in the productivity of forests and surface dwelling plankton because of the disruption of photosynthesis
  - disruption of food chains
  - immune system suppression in animals
  - lower crop yields
  - increase in smog
  - change in the global climate

6 **Ozone Depleting Chemicals**

- The ozone depleting chemicals (below) drift into the stratosphere, where UV causes the release of highly reactive free chlorine.
  - Chlorofluorocarbons (CFCs) are used in:
    - coolants in fridges and air-conditioners
    - propellants for aerosol cans
    - styrofoam insulation and packaging
    - medical sterilizers

- Halons are used in many fire extinguishers, soil fumigants/ pesticides, and solvents.
- Methyl chloroform is used to degrease metals
- Methyl bromide is used as a fumigant
- Carbon tetrachloride is used in many industrial processes.

7 **Ozone Depletion**

$$CFCl_3 + uv \quad CFCl_2^{\cdot} + Cl^{\cdot}$$
$$Cl^{\cdot} + O_3 \quad OCl + O_2$$
$$OCl + O_3 \quad Cl^{\cdot} + 2O_2$$

- 2 ozone molecules react to form 3 oxygen molecules
- Reactive chlorine ($Cl^{\cdot}$)is freed to continue the process.

8 **Ozone Depletion**

9 **Ozone Depletion**

10 **Dobson Units (DU)**

- The Dobson Unit (DU) is a measurement of column ozone levels (the ozone between the Earth's surface and outer space).
- The size and intensity of the ozone hole is growing each year, as can be seen in the satellite photos below. In recent years, a similar hole has developed over the Arctic.
  - In the tropics, ozone levels are typically between 250-300 DU year-round.
  - In temperate regions, seasonal variations can produce large swings in the ozone levels and they can occur even in the absence of ozone depletion.
  - Today the depletion of the ozone is most closely associated with disposal of air conditioners and refrigerators.

11 **The Ozone Hole**

- In 2000, the extent of the ozone hole over Antarctica was the largest ever.
  - The ozone 'hole' is defined as a region with lower than 220 Dobson units.
  - The readings were taken between the South Pole (90 degrees south) and 40 degrees latitude.
  - Data were collected in the Southern Hemisphere spring each year (between 7 September and 13 October.
  - The ozone hole is most evident in the Antarctic Spring (October)

12 **Ozone Recovery**

- The problem of ozone depletion was first detected in 1984 when researchers discovered the region of thinner ozone over Antarctica.
  - Since 1987, nations have cut their consumption of ozone-depleting substances by 70%.
- Free chlorine in the stratosphere peaked around 1999 and is projected to decline for more than a century.
- Ozone loss is projected to diminish gradually until around 2050, but will peak in 2020 and then decline until the polar ozone levels will return to 1975 levels.
- It will take another 100-200 years for full recovery (to pre-1950 levels).

13 **Montreal Protocol**

- The Montreal Protocol is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone
- In 1973 Frank Sherwood Rowland and Mario Molina began studying the impacts of CFCs in the Earth's atmosphere.
- They discovered that CFCs were stable enough to reach the stratosphere where they released a chlorine molecule after being broken down by UV radiation.
- The phase out management plan included two phases:

- Chlorofluorocarbons phase out management plan & hydrochlorofluorocarbon phase out plan.

14 **Global Climate Change**

- The Earth's atmosphere comprises a mixture of gases including nitrogen, oxygen, and water vapor.
- Small quantities of carbon dioxide, methane, and a number of 'trace' gases are also present.
- Global warming is a term generally used to describe the gradual increase in the average global temperature of the Earth due to the increased levels of 'greenhouse gases'.
- Global warming and the greenhouse effect are the main causes of global climate change.

15 **Global Warming**

- Historically, the Earth's climate has shifted between periods of stable warm conditions and cycles of glacials and interglacials.
  - The current warmer period is partly explained by the recovery after the most recent ice age glacial period that finished 10,000 years ago.
  - However, the current warming trend has been compounded by human activity, in particular, the release of certain greenhouse gases, such as carbon dioxide and methane, into the atmosphere.

16 **Global Temperatures**

- The graph shows how the mean temperature for each year from 1860 until 2008 (pink bars) compared with the average temperature between 1961 and 1990. The smoothed curve shows the general trend indicated by the annual data.

17 **Greenhouse Effect**

- The term 'greenhouse effect' describes the natural atmospheric warming caused by gases such as water and CO_2 in the atmosphere, which act as a thermal blanket in the atmosphere, letting in sunlight, but trapping or absorbing the infrared radiation as heat that would normally radiate back into space.
  - About 75% of the natural greenhouse effect is due to water vapor with an increasing greenhouse effect there will be more water vapor in the troposphere.

The next most significant factor is carbon dioxide.
- Without this process Earth's temperature would be around 0°C.

18 **Accelerated Greenhouse Effect**

19 **Greenhouse Gases**
- Recently six gases or groups of gases have been name by the Environmental Protection Agency (EPA) in the USA as major contributors to the greenhouse effect.
- These gases are:

20 **Sources of Greenhouse Gases**
- Carbon dioxide (CO_2)
  - Combustion of fossil fuels (especially coal), & car exhaust
  - Burning rainforests
- Methane
  - Anaerobic respiration (landfills, belching and flatus from cows, sheep, and humans)
  - Fossil fuel production, rice paddies, and wetlands
- Chlorofluorocarbons (CFCs)
  - Leaking coolant from fridges and air conditioners
- Nitrous oxide (N_2O)
  - Car exhaust

21 **Relative Effects of Gases**
- CO_2 is the most recognized greenhouse gas but it isn't the most potent. Water is the most effective greenhouse gas because of the abundance of water in the troposphere.
- The Global Warming Potential (GWP) is a measure of how much a given gas can cause global warming.
  - CO_2 is set at a GWP of 1 and used to compare all other gases to:

22 **Changes in Atmospheric CO_2**
- Since the Industrial Revolution and the expansion of agriculture about 200 years ago, additional CO_2 has been pumped into the atmosphere.
  - This build up of atmospheric carbon dioxide will continue to warm the Earth during the 21st century.

23 **Greenhouse Gas Levels**

- The Intergovernmental Panel on Climate Change (IPCC) has collated records of the increases in many greenhouse gases:

24 **Arctic Temperatures**
- Every year for the past twenty years Arctic temperatures have been above average which has caused a major problem with ice sheet melting.

25 **Ice Sheets**
- From 1980 to 2008 the extent of the Arctic summer sea-ice sheet has almost halved.
  - 2007 had the lowest amount of ice ever recorded.

26 **Ice Sheets**

27 **Ice Sheets**

28 **Ice Sheets**

29 **Ice Sheets**

30 **Ice Sheets**

31 **Ice Sheets**

32 **Ice Sheets**

33 **Ice Sheet Warming**
- Ice sheets in the Arctic and Antarctic help regulate the temperature of the Earth.
  - The reflectivity (albedo) of the ice reduces the amount of heat retained from the Sun, lowering the air temperature. Polar regions radiate away more heat than they receive but remain at similar temperatures because of the transportation of heat through the ocean and atmosphere.
  - The cover of sea ice insulates the ocean from the extreme air temperatures in winter (the ocean remains at about 1°C as opposed to -10°C and below in the air).

34 **Retaining the Ice**
- The albedo of ice helps to maintain its presence.
- The more ice there is, the more heat is reflected from the Earth's surface.

35 **Losing the Ice**
- As the sea-ice retreats, more non-reflective surface is exposed.
- Heat is retained instead of being reflected.

36 **Chain Reaction Melting**

- The retreat of the ice sheet may reach a critical point where a chain reaction begins.
  - Warm waters in summer lead to ice forming later in the autumn than usual.
  - Thinner and less reflective ice forms, so more heat is retained in the atmosphere and ice forms later each year.
  - It is predicted that by 2050 there may be no summer ice in the Arctic.

37 **Kyoto Protocol**

- Reducing carbon dioxide emissions is not easy as they are the end-product of fossil fuel combustion, and modern societies are powered by fossil fuels.
  - The Kyoto Protocol is an international treaty on climate change. It aims to reduce greenhouse gas emissions through the creation of an international market in carbon credits.
  - Countries can receive credits through various shared 'clean energy' programs and 'carbon dioxide sinks' in the form of forests and other systems that remove carbon dioxide from the atmosphere.
  - These credits could be used to promote environmentally sensitive agriculture globally.

38 **Carbon Credits**

- Carbon credits are also a way of measuring and regulating the emissions output of industry.
- Each tonne (1000 kg) of carbon dioxide is given a credit.
- The credits may be bought or sold on an exchange.
- The value of the credit depends on:
  - the quality of the carbon sink (e.g. validated sources)
  - the demand for the carbon credit

39 **Carbon Trading**

- Carbon trading allows companies to buy carbon credits from others who are not using them.

40 **Carbon Trading**
- A “polluting” company realizes it will produce 30,000 tons more CO_2 than its allowable limit, buys 30,000 carbon credits from the exchange at $2 a credit and pays $60,000.

41 **Carbon Trading**

42 **Carbon Trading**

43 **Carbon Trading**

44 **Carbon Capture**
- Coal and oil fired power stations produce around 60% of the world’s electricity needs.
- They also produce huge amounts of carbon dioxide.
- This is beginning to be addressed by the development of carbon capture systems, which reclaim the CO_2 produced during operation of the power station.
- The CO_2 will be stored in depleted oil wells or similar geological formations.

45 **Carbon Capture Systems**
- The carbon dioxide produced during the burning of the coal can be captured in one of three ways:
  - Oxyfuel combustion: if concentrated oxygen is used in the furnace only CO_2 is produced in the flue gas. This can then be compressed and stored or used.

46 **Carbon Capture Systems**
- Pre-combustion capture: Using a gasification process the coal is converted to CO_2 and H_2 from which the CO_2 is recovered leaving only H_2 gas, which is then combusted.

47 **Carbon Capture Systems**
- Post combustion capture: CO_2 is washed from the flue gas after combustion using calcium oxide.

48 **Carbon Storage**
- If the power station is close enough, the concentrated CO_2 gas stream may be piped directly to an injection site.
- Injection sites could include:
  - existing oil wells to help boost pressure and remove oil
  - depleted oil wells for permanent storage

- deep permanent aquifers where water is trapped. The CO_2 can dissolve with little chance of returning to the surface.
- Power stations further from injection sites will need to transport the CO_2 to the. The production of CO_2 in transport will be much less than the CO_2 captured from the power station.

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50 **Effects of Climate Change**

- Coastal resources: The sea level is expected to rise by 50 cm by the year 2100 causing flooding and submersion of low-lying areas.
  - This will be mostly the result of thermal expansion in the ocean (water expanding as it warms) and by some melting of glaciers and ice sheets.
- Forests: Higher temperatures and rainfall changes could increase the susceptibility of forests to fire, disease, and insect damage.
  - A richer CO_2 atmosphere will reduce transpiration in plants.
  - Loss of forests causes a reduction in photosynthesis, loss of a carbon sink and increased albedo.

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- Weather patterns: Under a warmer climate regime, regional changes in weather patterns such as El Niño and La Niña are likely. Changes in the intensity and frequency extreme weather conditions (hurricanes, typhoons and droughts) are also expected.
- Water resources: Increased evaporation rates and changes in rainfall are predicted to affect the availability of water for irrigation, drinking, industrial use, and hydroelectric power generation.

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- Health: Higher temperatures over longer periods may result in distribution shifts and increase heat-stress mortality in

susceptible organisms especially those specialist specie in fragile ecosystems.
  - Climate changes may produce new breeding sites for pests, e.g. mosquitoes, shifting and sometimes expanding the range of infectious diseases.
- Agriculture: Climate change may affect the viability of staple crops, such as rice, in some regions, particularly the developing countries. Can increase crop damage from pests and diseases.

53 **Loss of Biodiversity**
- Besides pollution and population growth, there are other causes of the loss of biodiversity.
- Habitat Destruction: played a key role in extinction especially related to tropical forest destruction.
  - In the simplest terms, when a habitat is destroyed, the plants, animals, and other organisms that occupied the habitat have a reduced so populations decline.
- Overuse: Overexploitation occurs when a resource is consumed at an unsustainable rate.
  - This occurs on land in the form of overhunting, excessive logging, and poor soil conservation in agriculture.
  - Overfishing affects sustainable yield.

54 **Loss of Biodiversity**
- Climate Change: Rising sea levels, snow and ice cover decreasing, earlier timing of spring events, and frequency of extremes.
  - Heat/cold waves, heavy/light precipitation, and stronger storms .
- Introduced Species: When barriers between ecosystems are blurred then the organisms can easily pass between barriers.
  - Unintentional introduction (mongoose in Hawaii) to control other organisms (rats) can have other effects.

55 **Maintenance through Conservation**
- The conservation ethic advocates management of natural resources for the purpose of sustaining biodiversity in:
  - Species, ecosystems, evolutionary processes, and human culture and society.

- Preserving global biodiversity is a priority in conservation designed to engage public policy and concerns affecting local, regional and global scales.
  - Natural capital, market capital and ecosystem services.

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